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# Preference for different urban greenscape designs: A choice experiment using virtual environments

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ABSTRACT

Nature in cities serves a multitude of purposes, one of which is that it provides citizens opportunities to recover from stressful daily urban life. Such stress recovering effects of nature can be experienced through urban green, which in urban planning and design contexts can be divided into large natural areas - urban green space - and small scale elements in urban streets: the urban greenscape. The current study aims at finding the extent to which various small scale natural elements in residential streets and their possible configurations influence citizens' preferences for those streets. The research was conducted through an online survey in four cities in the Netherlands ($n$ = 4,956). It used stated choice methods in a virtual environment street design. The method yielded high quality data, indicating that the use of virtual environments and imagery is suitable for stated choice research in the built environment.

The results show that especially trees very strongly influence preference, indicating they deserve more attention and space in cities. Grass, which is typically favored by local governments, and vertical green have the smallest effects in residential streets. Furthermore, the concept of greenscape intensity is introduced as the intensities of both the element and the configuration were found to be highly relevant. The results clearly show that the higher either of these intensities, the more likely a respondent will prefer the greenscape design. Furthermore, low intensity on the one can be compensated by high intensity on the other. With these results, urban design professionals and local governments can better trade-off the different aspects of costs versus positive effects of urban greenscape designs.

## 1. Introduction

In 2014, more than half of the earth's population lived in cities. Forecasts indicate that by 2050 this percentage will increase to 66% (UN, 2015). Although cities are dynamic and vibrant places to live, they also impose many mental and physical demands on their citizens resulting in different forms of stress. An increased chance of experiencing environmental stress comes from continuously having to stay alert to fast moving vehicles, protect one's own personal space and sort through a myriad of sensory input such as noise, smell and heat (Steg et al., 2013). Moreover, there are indications that social stress in urban environments is higher than in rural areas (Lederbogen et al., 2011). Opportunities for escaping from such stressors in urban environments are provided by nature and natural elements in cities. There are many ways that nature in cities can take shape and there are equally many ways in which nature affects the city, such as through shading and cooling (Dimoudi and Nikolopoulou 2003), air pollution control (Janhäll 2015) and other so called ecosystem services (Riechers et al., 2018a, 2018b). The current paper focuses on the psychological effects nature in cities has on urban dwellers. Parks, urban forests, grass strips, trees and gardens - together called *Urban green* - create places to relax, recreate and rest (Van den Berg et al., 2007; Hartig & Kahn, 2016), leading to psychological processes of restoration and offering important benefits regarding city dwellers' well-being (Ulrich, 1984; Kuo & Sullivan, 2001; De Vries, 2010; Ward Thompson et al., 2012; Kemperman & Timmermans, 2014; Ward Thompson et al., 2016; WHO, 2016; Zhang et al., 2017). Moreover, nature experience can lead to positive emotions (affect) through beauty (aesthetic preference). Both affect and preference are related to the psychological constructs behind stress restoration (Purcell et al., 2001; Hartig & Staats, 2006; Pearson & Craig, 2014; Lindal & Hartig, 2015; Hoyle et al., 2017; McAllister et al., 2017).

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Currently, research on urban green is mostly on large green entities in cities, such as parks, and on visiting such spaces as an intended activity. However, far more time in daily urban life is spent on activities other than visiting parks. Research even claims that for city dwellers experiencing nature has actually become a 'rarity' (Cox et al., 2017). Therefore, from a policy perspective, it seems logical to strive for a design that stimulates citizens to encounter urban green easily and frequently in order to optimize gaining the beneficial effects. This can be achieved by linking urban green to daily activity patterns in such a way that citizens encounter nature on a regular basis while going about their regular business in urban streets. Improving the design of urban green in streets then allows citizens to gain the beneficial effects of nature more, and more frequently. Preference for specific urban green designs can thus become a tool in attracting citizens to more restorative environments. As walking and cycling allow for more interaction with the environment than driving a car, even stronger effects could be expected in a country like the Netherlands because of its cycling and walking culture (Pucher and Buehler 2008, Fishman, Böcker et al. 2015). Such active modes of travel are in the Netherlands normal for both leisure and functional purposes, such as commuting or grocery shopping.

To facilitate focused research on the design of urban green specifically in streets more knowledge is needed on everyday small scale elements in cities, such as street trees, front yards, wall climbing plants, green strips and tiny parks, and their potential to influence choice of environment for activities and for travel between activities. We propose to make a distinction between large scale *urban green space* and small scale urban green in streets, which will be termed the *urban greenscape.* This distinction is supported by research that showed that especially for mental health effects there are relevant differences between urban green space and small natural elements in streets (Dillen et al., 2012). The distinction acknowledges that nature in cities is not always a *space* that is *actively* sought out, but can also be a single element 'accidentally' encountered. Furthermore, it allows research on both urban green space and the urban greenscape to be more specific and in depth.

The urban greenscape *design* is a certain combination of natural elements and their configuration in urban streets, which enables us to address the question whether certain design choices can increase the chance a person chooses a potentially more restorative place or route. The current study focuses on whether people have: (1) identifiable and quantifiable *preference* for (2) *elements* and (3) *configurations* in the urban greenscape design, more specifically (4) in *residential streets*.

### 1.1. Preference

Regarding preference from the perspective of environmental psychology a clear relation between nature in general and preference has been well established. However, this is less so at element and configuration level (Purcell et al., 2001; Joye & Bolderdijk, 2014). The strength of the psychological effects at the level of specific urban greenscape elements and configurations is unknown and potentially small. Therefore, a research method should be used that minimizes influences other than those due to the urban greenscape. A barking dog, or a car driving past, could possibly influence the valuation of the greenscape. Also, emotional and functional values as well as memories associated with a place could take the focus away from the actual environment. For those reasons, virtual environments have advantages over real ones. As disadvantages, the use of virtual environments has issues regarding saliency (relevance for decision makers), credibility (scientific adequacy) and legitimacy (respectful of different values and beliefs), but these issues are becoming less problematic due to rapid development of technological possibilities (Lovett et al., 2015).

A specific risk of using virtual environments is that the assessment is of visual stimuli only, instead of the integral perception of an actual environment, including sounds, smell and wind, all adding to the nature experience (e.g., Kjellgren & Buhrkall, 2010). Moreover, weather aspects can influence the general perception of an environment (Laing et al., 2009). Such other stimuli are not (yet) always easily and realistically incorporated in a virtual environment. However, research shows that, with regard to aspects of restorativeness including affect and preference, the use of virtual environments does not lead to significantly different results compared to the use of realistic or real environments (Hartig et al., 1997; Laing et al., 2009; Kjellgren & Buhrkall, 2010; Pals, 2012; McAllister et al., 2017). Furthermore, Orland (Orland, 2015) points out, that social and cultural aspects of a virtual environment and other (virtual) participants in it, may influence behavior in virtual environments. Therefore, if not under research, such cues need to also be minimized in a virtual environment. Using Lovett and colleagues' evaluation of different visualization options (Lovett et al., 2015), the use of rendered still images seems appropriate for the purpose, audience, available resources and limited need for interaction of the current study.

### 1.2. Elements and configurations

Regarding the elements and configurations, first, research generally has looked at parks and not at residential streets. For instance Nordh and colleagues (Nordh et al., 2011) found trees and grass to be the most relevant natural elements in small parks for choosing parks designs when fatigued. They also used bushes, flowerbeds and water in the survey on restoration likelihood in small parks (Nordh et al., 2009; Nordh et al., 2011). Jorgensen and colleagues (Jorgensen et al., 2002) used different configurations, with different levels of 'enclosure' in park design, aligning trees along the sides of a path and looking at understory growth in relation to preference. Second, when research has looked at (residential) streets, it generally has measured psychological restoration rather than preference. An example is the research that focused on stress reduction in relation to trees, their density, and grass in residential streets (Jiang et al., 2014). Third, research has sometimes addressed preference at street level, but has not specified to the level of elements. An example of this is research that acknowledged the importance of trees while also looking at other roadside vegetation in inner city streets, while not further specifying different typologies of that other roadside vegetation (Weber et al., 2014). One study that did zoom in on preference for elements on street level is by Todorova and colleagues (Todorova, Asakawa et al. 2004). As previous studies showed the relatively large influence of trees and the fact that combining trees with ground covering green elements strengthened this influence, they studied the importance for preference of flowers, hedges, grass and soil in relation to trees. They did, however, not study them as separate elements. They found that in combination with trees, flowers, especially brightly colored ones, were most preferred in streets, presumably due to their aesthetic and psychological benefits. Second most preferred were hedges, third was grass, then soil only and last come the option with no natural space below the trees.

Possibly, the separate influences on preference of elements and configurations are so small and interconnected to the rest of the environment that so far it has not been feasible to establish them individually. Therefore we introduce *greenscape intensity* as a measure of (visual) impact of the urban greenscape in the total (visual) environment. Elements with high visual impact, such as trees, have high intensity, while elements with low visual impact, such as grass or vertical green, have low intensity. Likewise, configurations with multiple elements have high intensity, while configurations with few elements or just one element have low intensity. Greenscape intensity is thus derived from both the elements and the configuration. The current study can shed more light on how greenscape intensities interact and relate to preference.

We state the following main research question: to which extent do different elements and configurations in urban greenscape designs influence preference as measured through choice behaviour? More specifically will be addressed: are the separate influences of different

**Table 1**
The elements, element subtypes and configurations.

| Element | Subtype | Configuration (c = concentric, single or one patch, l1 = linear on one side of the street, l2 = linear on both sides of the street) Code | Description |
|---|---|---|---|
| Trees | Absent | T0 | No trees |
| | Small | Tsc | Single small tree |
| | Ts | Tsl1 | Row of small trees on one side of the street |
| | | Tsl2 | Rows of small trees on both sides of the street |
| | Large | Tlc | Single large tree |
| | Tl | Tll1 | Row of large trees on one side of the street |
| | | Tll2 | Rows of large trees on both sides of the street |
| Horizontal green | Absent | H0 | No horizontal green |
| | Grass | Gc | One patch of grass |
| | G | Gl1 | Grass strips along one side of the street |
| | | Gl2 | Grass strips along both sides of the street |
| | Flowers | Fc | One patch of flowers |
| | F | Fl1 | Flowers along one side of the street |
| | | Fl2 | Flowers along both sides of the street |
| | Hedges | Hc | One patch of hedges |
| | H | Hl1 | Hedges along one side of the street |
| | | Hl2 | Hedges along both sides of the street |
| Vertical green | Absent | V0 | No vertical green |
| | Vertical green | Vc | Wall climbing plants on a single house |
| | V | Vl1 | Wall climbing plants on several houses on one side of the street |
| | | Vl2 | Wall climbing plants on several houses on both sides of the street |

greenscape elements and configurations significantly distinguishable and quantifiable in relation to preference? Which elements and configurations add most to preference and which least? And, do more and larger green elements (high intensity) lead more to preference than fewer and smaller green elements (low intensity) do?

## 2. Method

In order to explore the relation between preference and elements and configurations of the urban greenscape, we constructed a stated choice experiment as part of a larger survey about the design of urban greenscapes as restorative environments.

### 2.1. Participants and survey

The local governments of the Dutch cities of Breda, Eindhoven, ‘s Hertogenbosch and Tilburg participated in the data-collection. These cities are the largest cities in the Province of Noord-Brabant and all had a population between 140,000 and 225,000 inhabitants at the time of the survey (Statistics Netherlands, 2015). Each of the cities has a citizen panel, consisting of citizens who volunteer to give the local government feedback on actual or proposed policy. Through the local governments, we sent the panel members a link to an internet questionnaire. In total the four panels consist of slightly more than 15,000 potential respondents with an overrepresentation of ethnic Dutch, people with a high education level and males. Subgroup analysis can provide insights into relevant differences in subgroups. The response rate is generally high, which, combined with the substantial number of potential respondents, is an important advantage. As the panels receive several questionnaires a month, the local governments put restrictions on the burden imposed on the respondents per questionnaire.

The questionnaire was constructed using an online-survey-system of the university (Jessurun, 2014) and consisted of five parts. It started with questions about the current urban greenscape in the respondent’s city, including whether they would like anything to be improved as a measure for satisfaction. After this followed a choice-task as the second part and a task to rate greenscape designs on Restoration Likelihood (RL) (Lindal and Hartig 2015) as the third. Fourth were questions about sociodemographics (gender, age, education level, household, income, ethnic background), and fifth a question about willingness to participate in a follow-up survey. Throughout the survey, respondents had the possibility to make open remarks at certain points as well. The order of the questionnaire parts was specifically chosen to first establish the broad topic and then ask respondents to make choices, for which they did not need to be familiar with the images of greenscape designs. After that, respondents would look more closely at the different greenscape designs in order to rate it; a task where being already familiar with the images would be an advantage rather than a disadvantage. This study focuses on the choice task of the survey in combination with the satisfaction and sociodemographic data. The results of the RL rating task is not part of this study and will be addressed in a separate research paper.

The survey was constructed in collaboration with the four local governments and was tested several rounds on language, understandability, logic, and feasibility (time and effortwise). The layout of the surveys differed in city name and logo. The questions differed only in the last question about the follow-up survey, which was not added for 's Hertogenbosch where the policy on the use of the citizen panel would not allow it. The survey was in Dutch and in this article the English translations of the questions are used.

### 2.2. Attributes of the urban greenscape in virtual environment residential streets

For creating the greenscape designs, we selected three main types of natural elements in residential streets, based on the literature review in the introduction section under elements and configurations, and what is commonly found in Dutch residential streets: trees, horizontal green and vertical green. For each element we defined subtypes. The trees could be small (below or at building height, approximately 8 m), large (taller than the buildings, approximately 13 m), or be absent. Horizontal green in a strip one meter wide could be grass, flowers, hedges (approximately 50 cm tall), or be absent. Vertical green could consist of wall climbing plants, or be absent. The subtypes were further differentiated through three possible configurations. A subtype, if present, could be configured as concentric or single (c), linear on one side of the street (l1), or linear on both sides of the street (l2). Table 1 shows an overview of the elements, the possible element subtypes and their configurations.

A computer model of an empty modern residential street was built

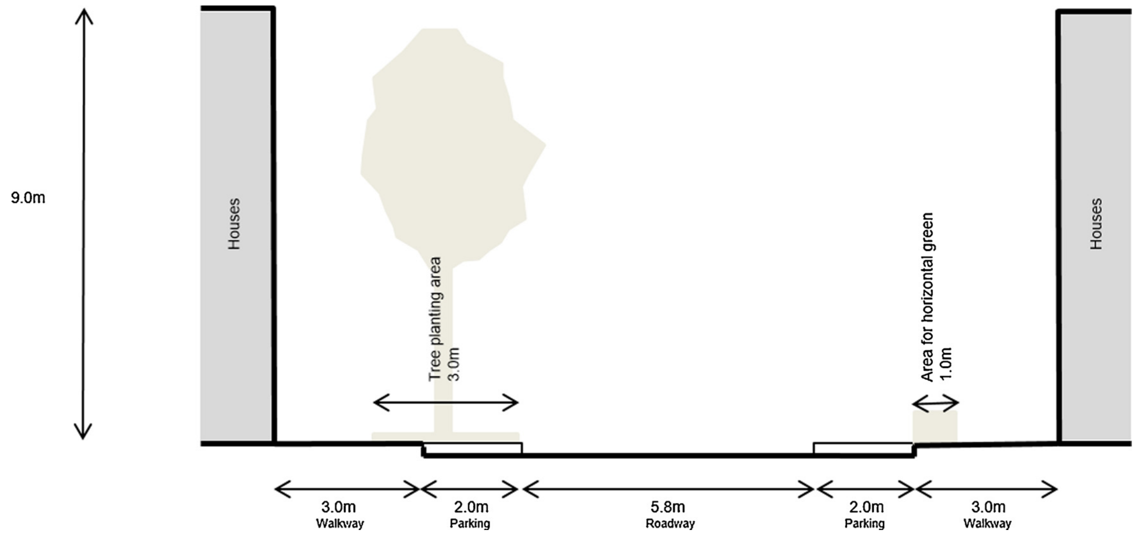



**Fig. 1.** Cross section of the virtual street design, including the main dimensions.

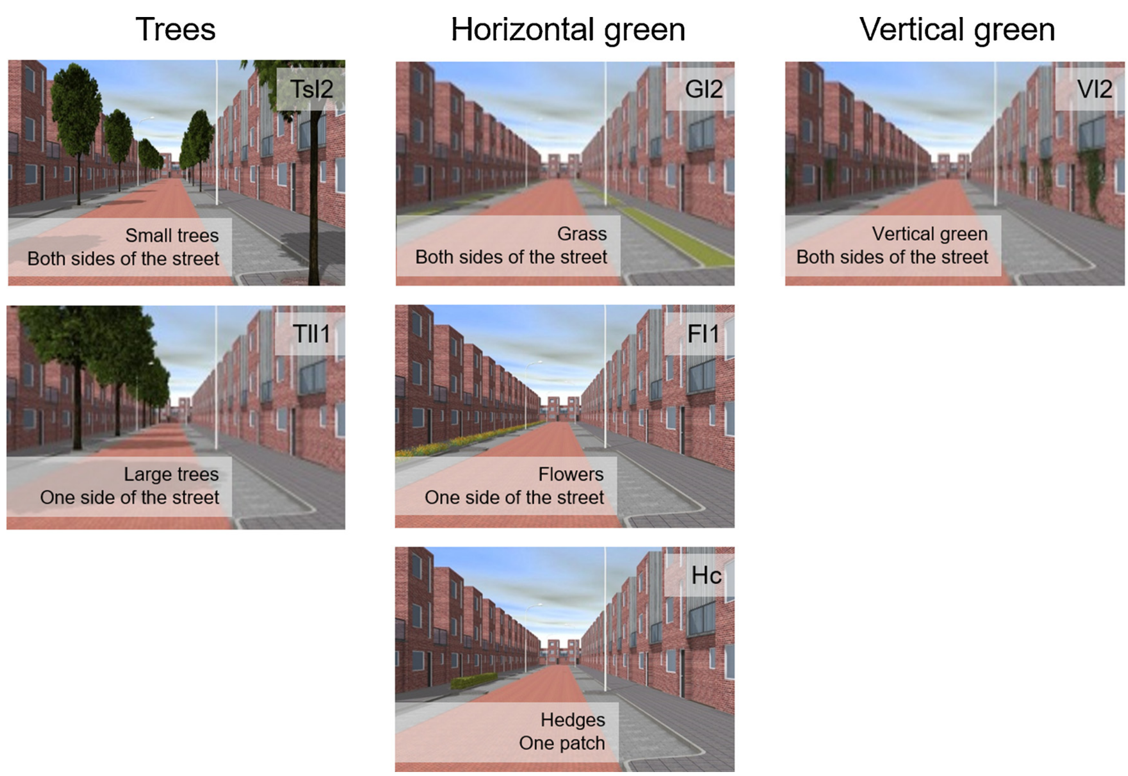



**Fig. 2.** Examples of street profiles with the different element subtypes and configurations.

by the Reality Center of Groningen University using 3DSMAX (Autodesk, 2013) and Photoshop (Adobe Systems, 2013). The street was meant to look very ordinary and as if it may be found in any Dutch town. It was based on Dutch norms regarding layout, street widths and sizes (CROW, 2012). Besides street lights, we left out all other elements in the street. Fig. 1 shows a cross section of the virtual street including the dimensions. The greenscape elements were then added to the 'empty' street, using generic representations of the elements. The virtual environment did not depict specific species of for instance flowers or trees. Fig. 2 shows an example of each element subtype and configuration in the street.

The wish to also explore interactions between the variables trees, horizontal green and vertical green required a full factorial research design. Combining the three variables with respectively seven, ten and four levels, generated 280 different greenscape designs. The variables were dummy coded, allowing comparison to the empty street (T0, H0, V0) as the base alternative.

### 2.3. Choice task

The choice task started with creating an implied feeling of being to some extent tired and not needing to rush, by presenting the respondents the following scenario:

> *"You've had a busy day. You are walking home. The two streets you see, are the two options you have; both are logical routes home and they are identical in distance to walk. The question is: through which street would you prefer to walk home?"*

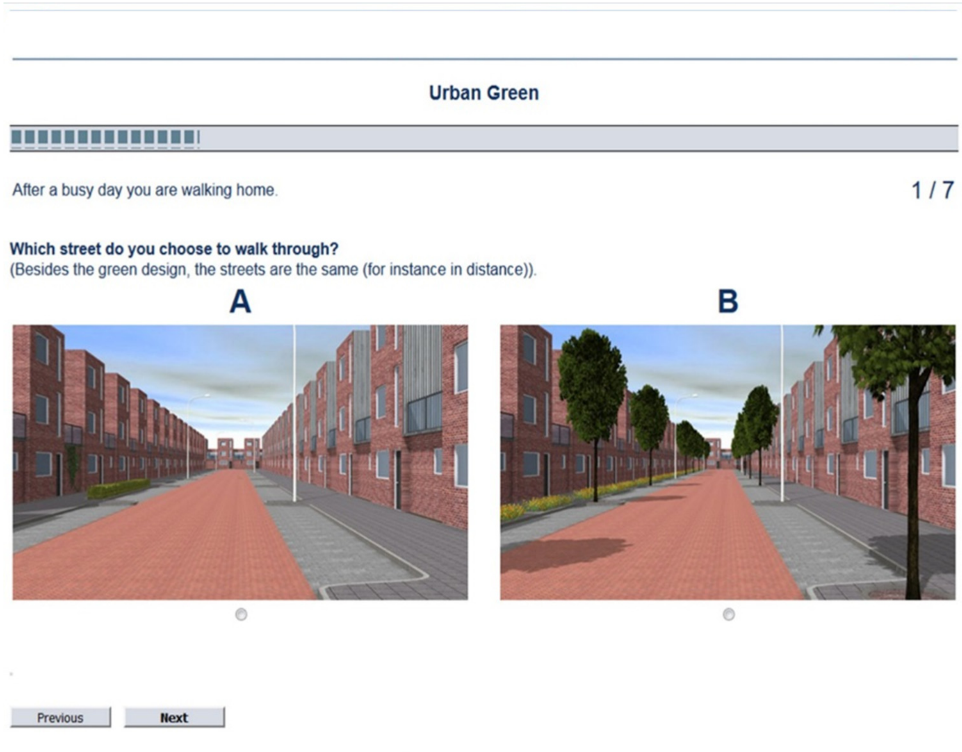



**Fig. 3.** Screenshot of the choice task in the online survey.

To reduce the burden on the respondents, as required by the municipal panel administrators, respondents were presented no more than seven choice sets, each a combination of two different street profiles. Limiting the number of choice sets was mainly necessary because of constraints in the other main part of the larger survey (not included in this paper), in which respondents were asked to rate the profiles on several statements. Such a task puts a higher burden on respondents. Therefore, the municipalities asked that no more than eight profiles would be used per respondent. In order to optimize the number of choices made in the choice task when using (only) eight profiles, the following procedure was used. Eight greenscape designs, or profiles, were randomly selected per respondent. With these, seven choice sets were created by presenting one and the same profile all seven times in the picture on the left, while the other seven randomly selected profiles were consecutively in random order presented in the picture on the right. For each choice set (see Fig. 3 for an example), the respondents were asked to make a choice through the following question:

> *"After a busy day you are walking home. Which street do you choose to walk through? (Other than the design, the streets are the same (for instance in distance))."*

Stated choice methodology assumes that when people have a choice between different alternatives, they will choose the alternative with the highest utility, which is defined as 'the level of happiness that an alternative yields to an individual' (Louviere et al., 2000; Hensher et al., 2005). Differences in utility are in this case not so much about getting home, as the routes are presented as identical in relation to getting home (e.g., in distance and safety). Utility then is derived from the environment the route is in, as that is the only relevant difference between the two alternatives. Furthermore, the question was formulated this way so that respondents would have to make a choice. 'No choice' is not a realistic option in the context (Nordh et al., 2011) as the respondent has only these two options available in order to get home. Last, the scenario carries the message that the street (or route) that the respondent chooses is not the street with their home. This prevents a potential influence of 'Not In My BackYard' (NIMBY) emotions, because even though people generally enjoy nature and experience psychological benefits because of it, they may also experience nuisance through for instance less parking space in front of their homes, leaves to rake, or bird poo to wash off their car. By setting the scenario to walking *through* a street on your way home, the natural elements are something they pass by in other streets and thereby cannot be causing any side effects in the street with their homes.

We chose the pedestrian perspective for instrumental reasons. First, the design of the street easily facilitates walking, and second, walking is an activity that allows good interaction with the environment due to its natural low speed. Third, there are clear indications that 'greenness' and 'trees' in cities encourage walking as a mode of transport (Sarkar et al., 2015), and that, fourth, walking is a common mode of transport in neighborhoods (Ferreira et al., 2016). Last, in Dutch culture, walking (and cycling) is a common mode of transport for both functional and leisure purposes. Walking through a street thus conforms with the aim of linking the design of the urban greenscape to daily activity patterns.

### *2.4. Execution and response*

In November and early December 2014 the respondents received an invitation to participate in the survey through the regular municipal channels. The respondents were invited on consecutive weekdays for Tilburg, Breda and 's Hertogenbosch and for Eindhoven a week later. This spread was to prevent possible overload on the university server and to fit in the planning of the participating cities. The respondents could enter and complete the survey for a period of 21 days for their respective cities. The invitation was sent to a total of 15,204 different e-mail addresses. The survey was started a total of 6,889 times (45% response rate), more than half of which were on the first day per city. Of the surveys started 5,026 were fully finished (73%). Premature stopping happened mostly in the first parts of the survey: approximately 20% did not finish the choice task. During the survey weeks, we received 10 e-mails with remarks from respondents, of which three addressed a part of the survey that did not seem to work. This is a positive sign about the stability of the survey system.

A data check led to the following actions. First, some responses were taken out of the data set due to unusable answers, for instance a negative or zero age, for which no check was built into the survey. Second, we noticed that there were very few non-Dutch respondents (1.6%) compared to the 6.5% proportion of non-Dutch in the actual population of the cities (Statistics Netherlands, 2015). Moreover, there was a very large variety in different nationalities within the group of non-Dutch respondents. In order to get more robust results for the respondents that considers themselves Dutch, we left the data of the non-Dutch out of the main analysis. After these two data checks, 4,956 fully finished surveys, consisting of 34,692 choices, remained for further analyses. The included respondents spent an average of 9 minutes on completing the survey when eight respondents who took more than 3 hours to complete the survey were excluded from of the calculation. The sample from a total combined population of the four cities of 717,202 Dutch citizens (Statistics Netherlands, 2015) was not fully random as the respondents came from a panel which itself was not random. The group of respondents was skewed from the actual population (Statistics Netherlands, 2015) concerning gender (61% male vs 49.9% in the 4 cities), age (older, average age 55.4 versus 40.3 in the 4 cities), and education level (higher 61.7% versus 27.5% in the Netherlands) and income (higher). The municipalities confirmed that that was in line with the sociodemographic characteristics of the panel members. Analysis of subgroups could show if there are relevant differences.

### 2.5. Randomization of choice sets

The eight profiles shown per respondent were selected randomly and shown in random order. In that regard, an order effect was avoided. However, per respondent the seven choice sets always showed the same one profile in the left picture and the seven others in the right respectively. Respondents could have a preference for either the left or the right side, which would result in a skewed choice pattern, regardless of the content of the picture. Such a skewness could also result from the fact that the left picture remained the same for all seven choice tasks per respondent, inducing familiarity. We checked whether the choices were influenced by the side the alternative was presented on, by observing the numbers of times the left and right options were chosen. Over all 34,692 choices made, nearly exactly half were for the left and half for the right picture (17,344 vs 17,348). Subsets per city showed similar results, leading to the conclusion that there is no indication that the choices were influenced by the side the pictures were on.

### 2.6. Tools for analysis

For statistical analysis we used the stated choices to calculate a set of parameters for the independent (greenscape) variables estimating the utility of the different choice alternatives. This Stated Choice Modeling results in a model that best predicts the choices actually made, based on the principle of utility maximization behaviour (Hensher et al., 2005). Starting with a general Multinomial Logit (MNL) model, we explored different modeling techniques and procedures including Mixed Logit (ML) models. To assist in calculating these models we used NLOGIT5 (Econometric Software, 2012) software.

The randomization of the choice sets brought the risk of unequal numbers of times profiles were offered. However, as stated choice methodology looks at the specific variable values within the profiles, the numbers became much larger and accordingly the unbalance negligible considering the specific statistical procedures of the MNL and ML models.

## 3. Results

### 3.1. Model estimation

We estimated a ML model, to also allow for individual preference heterogeneity (Hensher et al., 2005). First we determined which of the main effect parameters would be treated as random, by establishing whether the randomness of the corresponding parameters was significant (at $p < .10$). Second we removed in several steps of model estimations the attributes with non-significant parameters (significance at $p < .10$). The resulting model had an $R^2$-adj (McFadden) of .503 ($n$ = 34,692, panel effects, 1,000 Halton draws, 25 included attributes of which 15 with random parameters for main effects, Normal distribution for random effects). Values of $R^2$ between .2 and .4 are, for this field of research and the method used, considered to be very good (McFadden, 1978; Hauber et al., 2016), which makes the adjusted $R^2$ for our model an excellent model fit.

We further explored potential sources of heterogeneity by modeling while specifically looking at gender, which is considered to be of influence on nature experience (e.g., Jiang, Chang et al. 2014), and satisfaction with the current urban greenscape. For the latter we used the answers to the question whether the respondent had a wish to improve anything about the urban greenscape in the neighborhood. Besides adding those aspects, we used identical modeling instructions.

### 3.2. Parameter values

As the urban greenscape variables ($X_a$) were dummy coded, they indicated whether a certain greenscape element, or a combination of two or three, was present (value 1) or not present (value 0). Therefore, if present, the part worth utility - the utility added compared to the base alternative - was for that greenscape element equal to the parameter value ($\beta_a$). The model parameters are presented in Table 2.

*Main effects and configuration*

We explored the influence of greenscape elements and their configurations by plotting the parameter values per element (y-axis) against the different configurations (x-axis) (Fig. 4).

The graph in Fig. 4 clearly shows two things. First, there is a hierarchy in the part worth utilities of the elements (per configuration). Large trees had the highest parameter values, followed by small trees, hedges and flowers. Grass and vertical green had the lowest values.

The values for trees were per configuration much higher than those for the other elements (with factors from 1.6 between Tsc and Fc, to 10.6 between Tll2 and Vl2). Within the element 'Trees', the values for large trees were approximately 1.4 times as large as those for small trees for all configurations. Moreover, the presence of only double rows of large trees (Tll2) provided more value towards preference than almost any combination of other elements and configurations. It seemed the larger the element intensity, the larger the influence.

Second, we found a general pattern where parameter values likewise increase when moving from low configuration intensity with few elements (left) to high configuration intensity with many elements (right).

Using these findings, we next plotted the same data in a 3D-space with value per configuration and per element (Fig. 5). The plot shows that higher intensity on either axis leads to higher parameter values (main effects only in this graph) and thereby to a larger chance of preferring and choosing a certain street profile.

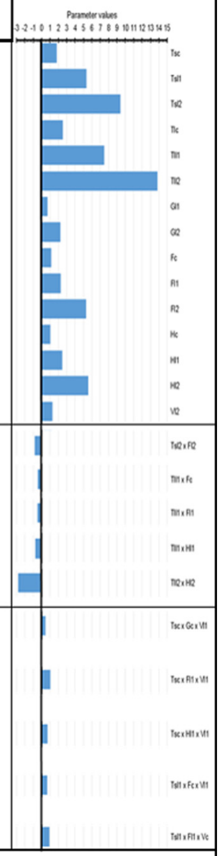
The two dimensions were comparable: a single large tree (high element intensity and low configuration intensity) had an approximately equal parameter value as rows of flowers on one side (medium element intensity and medium configuration intensity) and rows of grass on two sides of the street (low element intensity and high configuration intensity). Values on the different intensity dimensions seemed to interact and to be able to compensate each other.

Focusing on the main effects of elements and their configurations, the variable with the largest parameter value in the model was for double rows of large trees (Tll2). Second largest was for double rows of small trees (Tsl2) and third largest was for a single row of large trees (Tll1). Medium values were found for a single row of small trees (Tsl1), double rows of flowers (Fl2) and double rows of hedges (Hl2). Low

**Table 2**
Parameter estimates of the ML-model.

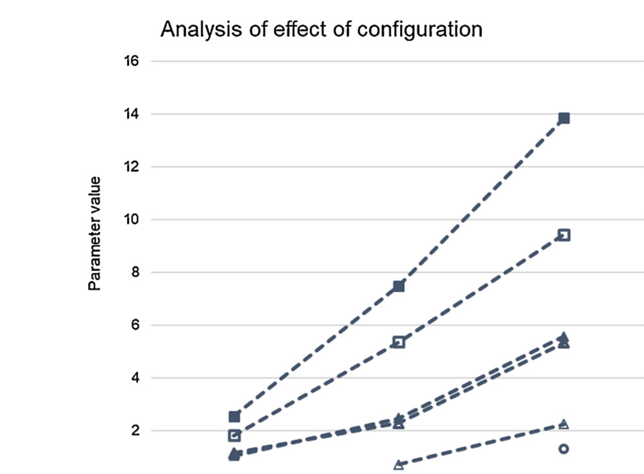
$R^2$ adjusted = 0.503 (McFadden)

| variable code | variable | para-meter | value[1] | | Random parameters st.dev. | |
|---|---|---|---|---|---|---|
| Tsc | Small tree single | β1 | 1.82 | *** | 0.67 | ** |
| Tsl1 | Small trees 1 side | β2 | 5.36 | *** | 1.47 | *** |
| Tsl2 | Small trees 2 sides | β3 | 9.43 | *** | 3.58 | *** |
| Tlc | Large tree single | β4 | 2.54 | *** | 0.67 | * |
| Tll1 | Large trees 1 side | β5 | 7.48 | *** | 2.78 | *** |
| Tll2 | Large trees 2 sides | β6 | 13.84 | *** | 8.43 | *** |
| Gl1 | Grass 1 side | β8 | 0.71 | *** | 1.05 | *** |
| Gl2 | Grass 2 sides | β9 | 2.24 | *** | 1.82 | *** |
| Fc | Flowers single patch | β10 | 1.15 | *** | 0.81 | *** |
| Fl1 | Flowers 1 side | β11 | 2.28 | *** | 1.29 | *** |
| Fl2 | Flowers 2 sides | β12 | 5.33 | *** | 2.83 | *** |
| Hc | Hedges single patch | β13 | 1.05 | *** | 0.79 | * |
| Hl1 | Hedges 1 side | β14 | 2.47 | *** | 0.83 | *** |
| Hl2 | Hedges 2 sides | β15 | 5.57 | *** | 3.95 | *** |
| Vl2 | Vertical 2 sides | β18 | 1.31 | *** | 1.34 | *** |
| Tsl2 x Fl2 | Small trees 2 sides AND Flowers 2 sides | β48 | -0.83 | ** | | |
| Tll1 x Fc | Large trees 1 side AND Flowers single patch | β70 | -0.46 | ** | | |
| Tll1 x Fl1 | Large trees 1 side AND Flowers 1 side | β71 | -0.49 | ** | | |
| Tll1 x Hl1 | Large trees 1 side AND Hedges 1 side | β74 | -0.75 | *** | | |
| Tll2 x Hl2 | Large trees 2 sides AND Hedges 2 sides | β87 | -2.81 | *** | | |
| Tsc x Gc x Vl1 | Small tree single AND Grass one patch AND Vertical green 1 side | β119 | 0.47 | * | | |
| Tsc x Fl1 x Vl1 | Small tree single AND Flowers 1 side AND Vertical green 1 side | β131 | 1.04 | *** | | |
| Tsc x Hl1 x Vl1 | Small tree single AND Hedges 1 side AND Vertical green 1 side | β140 | 0.73 | ** | | |
| Tsl1 x Fc x Vl1 | Small trees 1 side AND Flowers one patch AND Vertical green 1 side | β155 | 0.66 | * | | |
| Tsl1 x Fl1 x Vc | Small trees 1 side AND Flowers 1 side AND Vertical green single | β157 | 0.95 | *** | | |




* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

[1]Parameter values indicate value added compared to the base alternative, i.e., a street design with no green elements.




| Configurations | c | l1 | l2 |
|---|---|---|---|
| Large trees | 2.54 | 7.48 | 13.84 |
| Small trees | 1.82 | 5.36 | 9.43 |
| Hedges | 1.05 | 2.47 | 5.57 |
| Flowers | 1.15 | 2.28 | 5.33 |
| Grass | | 0.71 | 2.24 |
| Vertical Green | | | 1.31 |

**Fig. 4.** Parameter values for the main effects per element and configuration.

values were found for all designs with the concentric configuration (c), flowers and hedges along one side of the street (Fl1 and Hl1) and grass and vertical green on both sides (Gl2 and Vl2). A very low parameter value was found for grass along one side of the street (Gl1). Of the main effects, the variables for one patch of grass (Gc), one house with vertical green (Vc) and several houses with vertical green on one side of the street (Vl1) had parameter values not significantly different than zero. Variables with low, or non-significant, values may not have a large influence by themselves, but could show relevant interaction effects when combined with other elements.

*Interaction and total effects*

In general, the interaction effects were small. Most interactions were not significant; only 10 out of 261 possible first and second order interactions were included in the model based on sufficient significance ($p < .10$). When significant, they generally had relatively small influences compared to the main effects. Interestingly however, a clear pattern did present itself: the significant first order effects all had negative values, while the significant second order effects all had positive values. Of the first order interactions, none included a combination with vertical green.

To calculate the total utility of a greenscape design, relative to the base alternative with no green, the parameter values for the main effects and the first and second order effects were summed. An example for the street profile with double rows of large trees (Tll2) plus double rows of hedges (Hl2) is given in Fig. 6, showing a tempering of total value due to the negative value for the first order interaction.

*Random parameters*

Random parameters were explored for the main effects, greatly increasing the value for $R^2$. Using random parameters for all significant main effects thus improved the model. From this we could conclude that for the main effects personal preferences seemed to play a

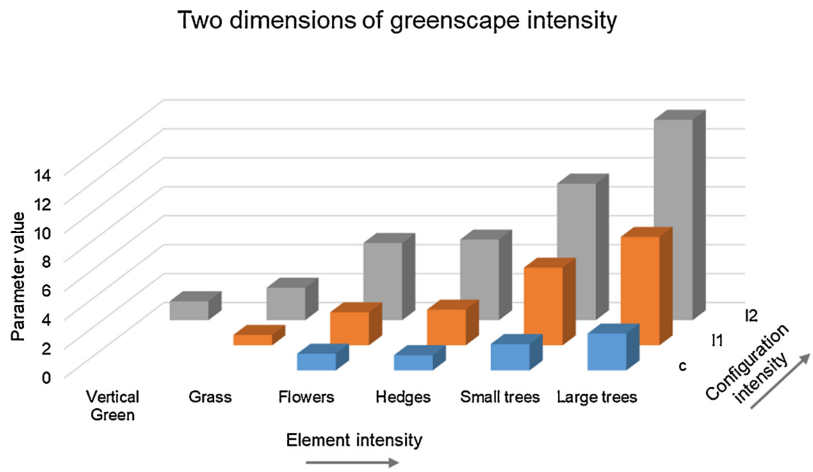



**Fig. 5.** Greenscape intensities in two dimensions in relation to values for the main effects.

significant role. All random parameter means were larger than the corresponding values for a corresponding MNL-model (i.e. without random parameters) and the standard deviations of the Normal distribution for the random parameters generally had sufficiently lower values than the means. This scaling to larger values and such spread is normal for the method and should typically be expected (Hensher & Green, 2003). The models incorporating gender and satisfaction with the current neighborhood urban greenscape design as potential sources for heterogeneity showed that for gender, the 15 main effects subgroup parameter values were all positive. Of those, a few of the medium to low intensity greenscape designs (one small tree, grass or hedges along one side of the street, and vertical green) the subgroup parameter values were not significant. The values consistently indicated that females attributed more value to trees and horizontal green. Regarding satisfaction with the current greenscape design in the neighborhood, the results indicate that for singular large trees (Tlc), flowers in one patch (Fc) and flowers linear on both sides of the street (Fl2), the satisfaction indeed is a significant ($p < .05$) source of heterogeneity. The corresponding parameter values were positive. This indicates that respondents that had wishes for improvement placed more value on those elements and configurations, than respondents with no wishes for improvement did. Furthermore, at the significance level at $p < .10$, ten out of the 15 random parameters showed significant differences between these respondent groups. All these were positive, suggesting that respondents with wishes for improvement might at a more general level attribute higher value to natural elements than those with no wishes for improvement.

## 4. Discussion and conclusions

### 4.1. Discussion

To focus specifically on natural elements in (residential) streets we distinguish between large natural surface areas (parks, urban forests) as urban green space, and natural elements in urban streets as the urban greenscape. This urban greenscape is where city dwellers are most likely to encounter natural elements on a regular basis, also when they may not actively seek them. We use individual choice mechanisms to seek out preferences for greenscape designs. The study concerns the respective and combined influences of different greenscape elements and configurations on preference.

In answer to our research question whether the separate influences of different greenscape elements and configurations are significantly distinguishable and quantifiable in relation to preference, we find a clearly distinguishable relation between specific elements of the urban greenscape and preference for an environment. This is true for elements, combined elements and different configurations of the elements within residential streets. Moreover, the high levels of statistical significance of the parameter values indicate that the influences are quantifiable on the level of elements and configurations. The parameter values show significant differences in the extent to which they influence the choice and preference for an environment. This offers opportunities for urban design professionals to consider different elements, configurations and combinations when optimizing a greenscape design for preference. It supports our idea that through design we may influence choices towards greener environments, which should allow citizens to then more often experience the benefits of nature.

In answer to our research question, which elements and configurations add most to preference and which least, the study shows that trees in general, and large trees in particular, provide a very high value towards preference, adding to the chance a certain greenscape design will be preferred and chosen. This is in line with literature reviews (in e.g., Lindal & Hartig, 2015). Possible reasons for the high values for trees are the larger proportion of the field of vision that is covered by green from trees (visual impact); the potential larger nature experience, due to view, sound and smell, possibly leading to an improved

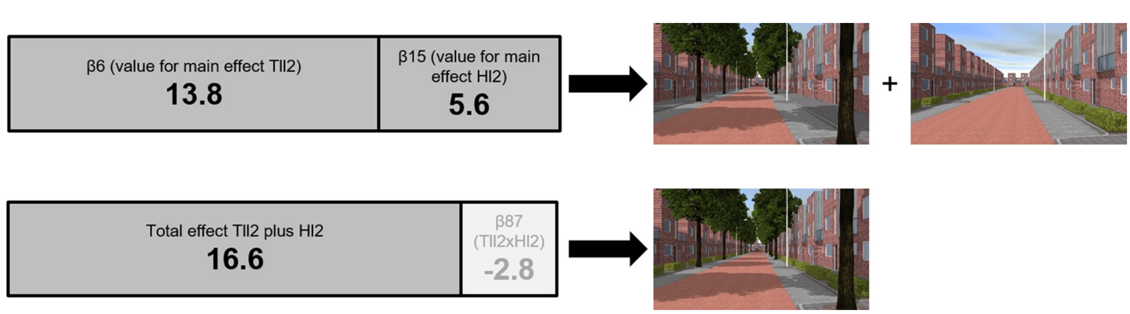



**Fig. 6.** Parameter values: example of total effect for a greenscape design with rows of large trees and hedges on both sides of the street.

perception of so called ecosystem services (Riechers et al., 2018a, 2018b); and functional reasons like the potential for shade under trees. This research confirms the importance of trees in residential streets (e.g., Mullaney et al., 2015) and puts a value to it, showing it is not just relevant, but very strongly so. This justifies more time, effort, budget and space to keep large trees healthy and present in residential streets, and to deal with problems they may cause in ways other than removing them. Furthermore, small trees should be given time and space to grow and become the large trees of the future.

The value of horizontal green in the urban greenscape depends on the subtype. Grass has far less value towards preference than hedges and flowers have. Relative to each other, the designs with flowers and hedges are more than twice as valuable for preference as those with grass in equal configuration. In practice, however, grass is often chosen for efficiency. Maintenance of grass is easier and cheaper than that of flowers and hedges. Furthermore, research on parks as opposed to residential streets, shows that grass is very much favored there from a user perspective (e.g., Arnberger & Eder, 2015). Possibly, this difference may be explained by the preference for 'overview', which in a park is well served by grass, while in a residential street there usually is clear line of sight and corresponding overview. Functional aspects are also likely to influence the difference. In a park, grass is a pleasant surface cover which can be used for several purposes (sports, sitting, laying down), while in residential streets, the natural elements have a mostly aesthetic and structural purpose, which may be better served by other types of natural elements than grass.

The influence of vertical green on its own is small, but combining these low intensity greenscape elements with other low intensity elements and configurations is efficient as the interaction effects are positive, adding effect beyond the sum of the main effects. This is in line with the general psychological phenomenon that humans perceive relative differences, instead of absolute ones: a small change on a low value has more impact, than the same change on an already high value. From a practical point of view vertical green does not require a lot of space and it typically is owned (both physically and psychologically) by citizens instead of the local government. Thereby it may be an efficient way of adding urban green experience to residential streets.

The main effects clearly show the relevance of the concept of greenscape intensity in relation to preference. Moreover, both element intensity and configuration intensity interact in the sense that a low intensity on the one, may be compensated by high intensity on the other and vice versa. The findings support a positive answer to our research question whether more and larger green elements (high intensity) lead more to preference than fewer and smaller green elements (low intensity) do. Reasons behind this could be comparable to the more generic potential reasons for the preference for trees: cover of large proportion of the field of vision, the larger nature experience and perception of ecosystem services.

The interaction effects are relatively small and thus only marginally influence the total value to either a higher level (positive parameter values) or to a lower level (negative parameter values). The significant negative interaction parameter values are not larger than the corresponding main effects, which leads to the conclusion that more green leads more to preference, even though in some instances the combined total value is smaller than the value one may expect based on the main effects only.

All significant first order interactions have negative parameter values and all significant second order interactions have positive parameter values, suggesting a pattern where combining two elements has a lower added value while combining three elements may have a higher added value, however, it has to be taken into account that a second order interaction will also entail two first order interactions. This pattern is supported when also looking at the non-significant interaction effects in the ML model when including all interactions: 81 out of the 99 first order interactions have a negative value and 119 out of the 162 second order interactions have a positive value.

Looking more closely at the significant interactions, a pattern seems to emerge: combining elements and configurations with medium to high intensity generally seems to diminish the total effect, while combining elements and configurations with medium to low intensity generally seems to increase the total effect. In other words: when combining more subtle urban green, the total is more than the sum of its parts. However, this pattern arises from only 10 significant interaction effects out of a total of 261, and is not clearly supported when also looking at the non-significant interaction effects in the ML model when including all interactions. Further research specifically on interactions is needed to more strongly establish consistency of patterns.

The added value of random parameters suggests there are significant differences between individuals. The analysis of differences between gender subgroups are in line with previous findings that females tend to have more positive attitudes towards the environment and nature than males (Zelezny et al., 2000). When distinguishing between respondents having and not having wishes for improving the urban greenscape in the neighborhood, we find indications that respondents with wishes attribute higher value to green elements than respondents without wishes do. This seems logical, as expressing wishes can be interpreted as the respondent not being indifferent to the subject and thus experiencing a value of urban green elements. A thorough further analysis of differences between sociodemographic subgroups will be addressed in a separate research paper. For now, due to the sample not being homogenous, the results should be interpreted with care in relation to other populations.

We research the relation between urban greenscape design and preference using a virtual environment in order to minimize external influences other than the differences in the urban greenscape. Images of computer generated virtual environments are proven to be effective in helping people make choices in hypothetical greenscape designs. The strict control exercised through such virtual environments led to excellent quality data, very high $R^2$-values (adjusted, MacFadden) and robust results, supporting the idea that research where the object of study is a mostly visual cue, using virtual environments in combination with choice methodology can lead to robust and significant results. It is however, important to take care when creating virtual environments, as the way the different green elements are visualized in the survey may play a role. For instance, in this survey 'grass' was depicted in a shade of green that did not stand out as much as the colorful (red and yellow) flowers or the high volume hedges. Also, in the l1 and l2 configurations for vertical green, we put wall climbing plants irregularly on most, but not on all houses. Both choices may have influenced the results.

### *4.2. Conclusions*

The aim of the current study is to find general guidelines to better equip urban planning and design professionals to optimize the design of the urban greenscape in order to increase the chance citizens will encounter or choose urban green environments in their daily activity patterns. City dwellers will then more often be in a green environment, reaping its benefits.

From a perspective of preference, the strong influence of trees in general and large trees specifically is a clear message to professionals working in urban planning and design that large trees in residential streets should be cherished, that removing large trees from cities should be discouraged and professionals should more often consider taking existing trees as a starting point for design, instead of starting a design with a clean slate. When planting new trees in residential streets the design should allow at least some of them to remain throughout their different growth stages. For both existing and new trees, from a design perspective, professionals can allow for more space for roots to grow, less pavement, more open soil, wider street profiles and increased distances to homes, especially on the shadow side. The knowledge that flowers and hedges may provide up to twice as much value as grass, may help local governments choose in their greenscape design, weighing the different aspects of cost versus effect. Recently, some cities have indeed started to provide more space to allow flowers and plants to grow more spontaneous and wildly along the roads, requiring less maintenance while simultaneously adding extra natural elements to the urban greenscape (Beatley, 2016). Last, allowing people to grow vertical green in streets along their home fronts seems a cost and space efficient way to add urban green experience, even though the effects were found to be relatively small.

### 4.3. Limitations and future research

The results are based on research in the southern part of the Netherlands, only taking into account people that considered themselves Dutch. The applicability of the results therefore should be considered for now at best to be limited to the general ethnic Dutch population. It would be interesting to see to what extent cultural differences lead to different results. Future research could aim at differences between regions in the Netherlands, and between countries, preferably also non-Western. Furthermore, we recommend to specifically seek respondents with immigrant backgrounds within Dutch society. It would also be good to extend future research to perceived and actual restoration in relation to preference and affect; to the value people attribute to the greenscape design (for instance in willingness to accept a longer travel time); and to the extent of the potential restorative effects of the greenscape when not actively and consciously seeking restoration, relative to an intentional restorative park visit.

## CRediT authorship contribution statement

**Robert P. Van Dongen:** Conceptualization, Methodology, Data curation, Writing - original draft, Writing - review & editing, Visualization, Investigation, Formal analysis, Funding acquisition. **Harry J.P. Timmermans:** Conceptualization, Methodology, Writing - review & editing, Supervision, Resources.

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